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PHOTOGRAPHIC SURVEYING IN CANADA

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The accurate survey of broken and lofty mountains is a task as difficult as the geographic results are interesting. The methods employed have varied with available appropriations, the limitations of topographer and instrument, and the character of the relief. The military engineers of a number of European countries, notably Italy and Austria in their Alpine domains, have done admirable pioneer work. Although in practical use for nearly forty years,[1] the photographic method has been brought to a high state of perfection during the last ten or fifteen years.[2] The following account gives an analysis both of the method and of its application to types of relief and climate that have baffled Dominion topographers ever since the survey of the rough lands of the western Cordillera was begun.

In western Canada there are large areas of broken country varying in elevation from low rolling foothills to snow-clad mountain ranges rising ten to eleven thousand feet above sea-level. The mapping of such country offers many difficulties. Ordinary methods of survey are impossible, except for very limited areas, and almost prohibitive owing to excessive cost.

In order to meet these difficulties, the method of photographic surveying was adopted, in the year 1886, by Dr. E. Deville, Surveyor General of Dominion Lands. In that year an extensive survey of the Rocky Mountains along the main line of the Canadian Pacific Railway was inaugurated. Since then the photographic method has been used in many localities.

Photographic surveying may be· used in any class of country where the topographic features are sufficiently marked to appear clearly in the

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[1] It may be of interest to note that one of the earliest applications of the method was made by W. Jordan in his survey of the oasis of Dakhel during Rohlfs's expedition to the Libyan Desert in 1873-74, mentioned in the May *Review*, p. 349 and footnote 2.

[2] Recent expositions of the subject are:

E. Deville: Photographic Surveying, Including the Elements of Descriptive Geometry and Perspective. Ottawa, 1895.

J. A. Flemer: Phototopographic Methods and Instruments, *Appendix No. 10* (pp. 619-735), *Rept. Superintendent U. S. Coast and Geodetic Survey for Year ending with June, 1897*. Washington, 1898.

A. Laussedat: Recherches sur les instruments, les méthodes et le dessin topographiques, Vol. 2 (in two parts). Gauthier-Villars, Paris, 1901 and 1903.

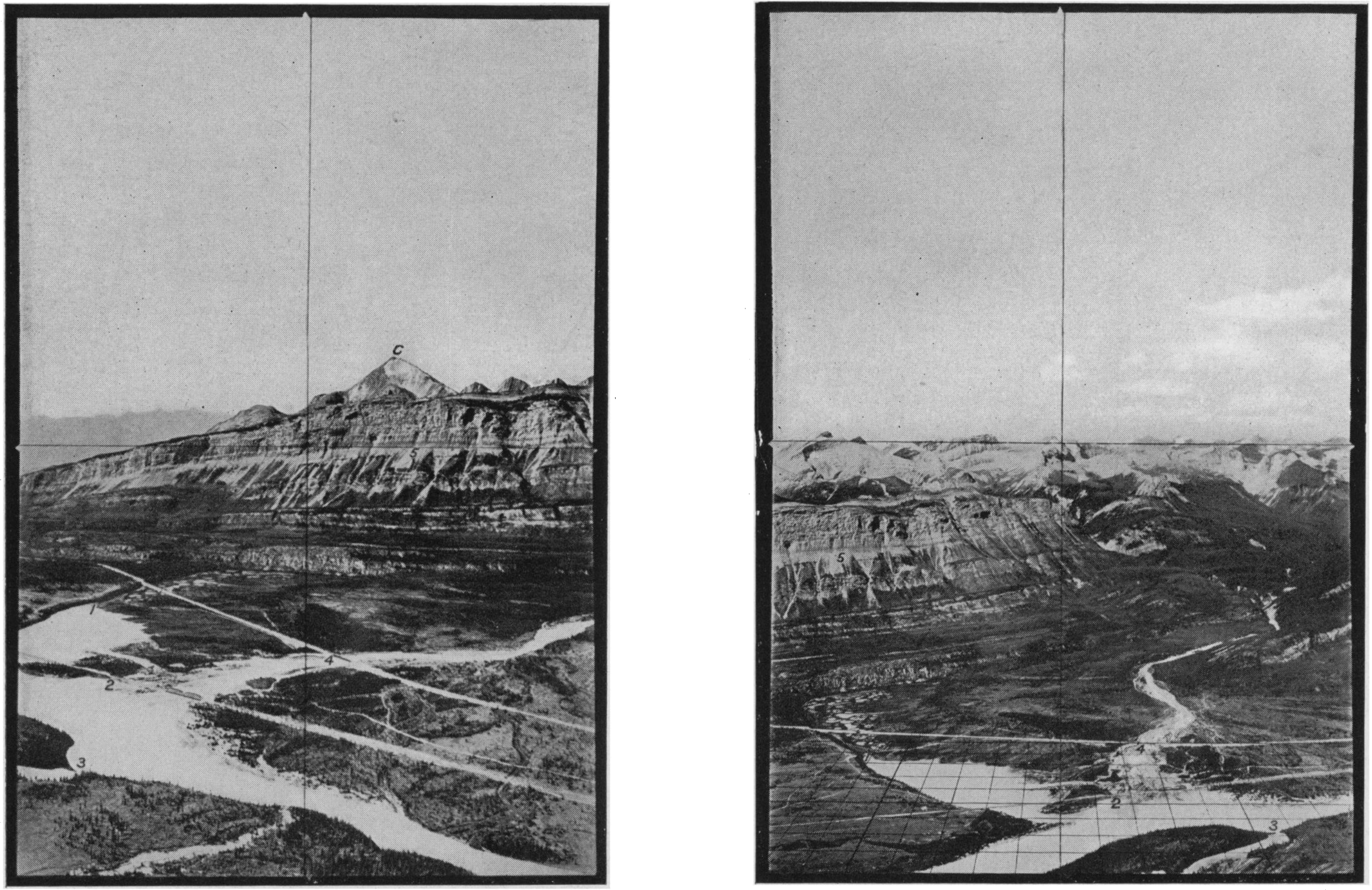
S. Finsterwalder: Die Photogrammetrie als Hilfsmittel der Geländeaufnahme, in "Anleitung zu wissenschaftlichen Beobachtungen auf Reisen," edit. by G. von Neumayer. 3rd edit., Jänecke, Hanover, 1906.

S. Finsterwalder: Photogrammetrie, in "Encyklopädie der mathematischen Wissenschaften," Vol. 6, 1, No. 1. Teubner, Leipzig, 1906.

W. Jordan: Handbuch der Vermessungskunde, Vol. 2, Chapter 16. 7th edit., Metzler, Stuttgart, 1908.

F. V. Thompson: Stereo-Photo Surveying, *Geogr. Journ.*, Vol. 31, 1908, pp. 534-551.

H. M. Wilson: Topographic, Trigonometric, and Geodetic Surveying, Chapter 14. 3rd edit., Wiley, New York, 1912.



FIGS. 1 and 2—Two partially overlapping views of rugged topography in Jasper Park in the Canadian Rocky Mountains, taken from two different stations with a camera equipped for photographic surveying. The relation of the two views is shown on Figure 3. Figure 1 is taken from the station marked B, and Figure 2 from the station marked A on that figure. The numerals 1 to 5 represent the same objects in both views and correspond with the points so numbered on Figure 3. The ruled network in the foreground of Figure 2 likewise corresponds with the network of squares in Figure 3.

photographs. The method is, however, best adapted to rugged country, such as the high mountain ranges of British Columbia and western Alberta. Here the season during which climbing may be accomplished with safety is short, and climatic conditions are often unfavorable. High winds, storms, clouds, and extreme cold are the rule, so that work must often be done hurriedly and under great difficulty.

On Canadian photographic surveys the essential instruments are a camera and a small transit. These instruments are of the simplest possible form. In this respect they show a marked contrast to the complicated designs of most European instruments.

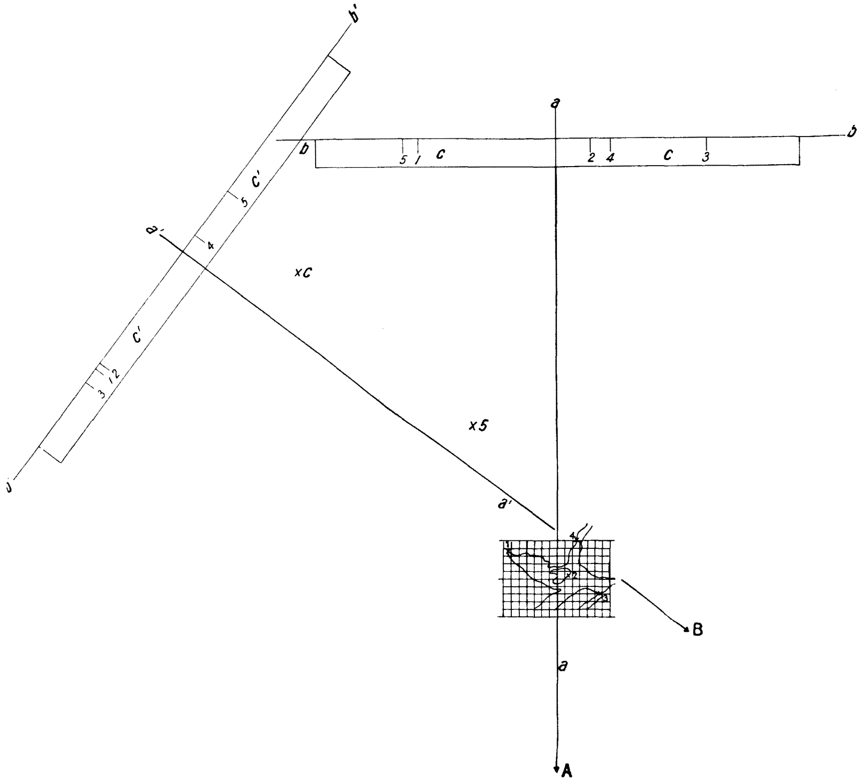


FIG. 3—Diagram to illustrate the method of constructing a map from two photographic views. For explanation, see the text. In practice the distance from *A* to *bb* and from *B* to *b'b'* is made equal to the focal length of the views and the distances of *1, 2, 3, 4, 5*, etc., from *Aa* and *Ba'* respectively are made equal to the distances of these points from the principal lines of the corresponding views.

The camera consists of an oblong metal box, open at one end and fitted into a strong outer wooden case. The metal box carries the lens and two sets of cross-levels which may be read through openings in the outer case. Inside the box there are two sets of diaphragms, and a shade is placed over the lens, when a plate is exposed, in order to eliminate all superfluous light. The instrument stands on a three-screw base, identical with that of the transit, so that the same tripod may be used for both. The camera may be used with the long side either horizontal or vertical. In the horizontal position the lens has a field of about fifty-one degrees and in the vertical of about thirty-six degrees. The extent of the field is shown by lines ruled on the case. The size of the plates is 4¾ by 6½ inches. The carrying case is made to hold the camera and twelve single plate holders. The total weight of the case with the camera and twelve plates is about twenty pounds.

The transit is a light instrument of the ordinary pattern, made by Troughton and Simms, London, with three-inch horizontal and vertical circles reading to minutes. The tripod has extension legs, three feet four inches long when extended, and twenty inches long when closed. When in use a bag is suspended between the legs and filled with stones, and the legs and bag are further blocked with stones so that it is rigid in any wind. For packing, the head is taken off and placed in the transit box, while the legs are placed in a canvas case designed to hold the box and the legs. The canvas case is fitted with shoulder straps for carrying. The total weight of the instrument complete is about fifteen pounds.

Owing to the excessive contrasts of Alpine scenery, ranging from snow in sunlight to deep and heavily timbered valleys in shadow, it would be impossible to get good photographs with an ordinary camera and lens. Moreover, there is always a certain amount of diffused light which tends to obscure the distant details. The remedy for the former is a plate having great latitude of exposure, and for the latter an orthochromatic plate with a yellow screen. In the last few years the Cramer "Slow Isochromatic" has been the plate principally used on Canadian surveys. The Seed "L. Ortho" has also given good results. In the beginning of the season of 1915, the Canadian cameras were fitted with Tessar lenses and Wratten and Wainwright "G" filters. Along with these, Wratten and Wainwright "Panchromatic Plates" were used and gave satisfactory results.

When in the field, it is important to select those points which give the best views of the surrounding country. This does not mean that the highest peaks are always the best. In photographs taken from a very high peak, the surrounding country often appears dwarfed, and the details do not show up as well as in those taken from a more moderate elevation. It must also be remembered that the higher the peak, the longer the ascent is likely to take, and the greater the likelihood of encountering sudden storms. Frequently very useful views may be obtained with little trouble from points of comparatively low altitude.

It is customary to take enough views from each peak to cover the complete circuit of the horizon. This means very little extra work for the surveyor in the field and the extra views are often of assistance in the office. It seldom happens, however, that all the views can be taken from a single point. Usually one or more camera stations are required on different parts of the peak. As a rule these may be located by reading angles on them from the central point and measuring the distance with a light tape. Angles must be read on at least one well-defined point in each view, preferably on two. The angle of elevation or depression should also be read on these points as it will serve to check the horizon line of the view if there should be any trouble in the office. It must also be constantly remembered throughout all the field work that all the country to be mapped must be seen from at least two points which subtend angles great enough to give satisfactory intersections and not too great to permit easy recognition of the same points as they appear in corresponding photographs, taken in pairs, one from each station.

For plotting purposes bromide enlargements approximately 10 x 14 inches in size are made from the negatives. To obtain satisfactory results, the enlarging must be very accurately done. This work is done at Ottawa with an enlarging camera made specially for the purpose.

In the office the triangulation is plotted by ordinary methods, depending on the nature of the control. This may vary from a precise triangulation to a reconnaisance survey, where the triangulation and the photography are carried on at the same time. Elevations of the stations and more prominent peaks are computed from the angles read in the field. Where necessary, corrections are made to allow for curvature and refraction.

Views from different stations showing the same country are then selected. Sufficient points are identified on each of two corresponding views taken from the different stations to show clearly the topography of the country. These points are then plotted on the plan and their elevations calculated from the photographs. Using these points as a guide, and with the photographs in front of him, the topographer is able to draw in his contours with an accuracy dependent chiefly on the number of points plotted and on the scale of his plan.

Figures 1 and 2 represent views from two stations shown as *A* and *B* in Figure 3. On these views, points *1* to *5* have been identified to illustrate the method of plotting. The principal and horizon lines, whose positions have been determined during the season, are first ruled on the views. The traces of the principal line and of the picture plane for each view are then laid down on the plan as shown in Figure 3, *aa, bb,* and *a'a'* and *b'b'* representing these traces respectively for Figures 2 and 1. The distances of the identified points from the principal line are then taken off on a slip of paper, a separate slip being used for each view. These slips are then placed on the traces of their respective views as shown by *cc* and *c'c'* in Figure 3. The line of sight to any point is then given by drawing a straight line from the station to the projection of the point as shown on the slip. By inserting needles at *A* and *B* and using fine silk threads or hairs, instead of actually drawing lines on the plan from each station, the intersections may be determined very rapidly.

The elevations of the points are taken out by means of the instrument shown in Figure 4, which was originally devised by Messrs. D. B. Dowling and H. Matheson of the Canadian Geological Survey. The arms *M* and *N* are of brass fastened rigidly together. *P* and *Q* are sliding bars, moving on the arm *M*. *R* is a swinging arm revolving around the center *O*. *P* and *R* are made of transparent celluloid, and on *R* a fine line *rr* is ruled radiating from the center *O*. The arm *Q* carries a scale corresponding to the scale of the map. The instrument must be made accurately so that, when the line *rr* is over the line *s*, the reading of the scale will be constant when moved along the arm *M*.

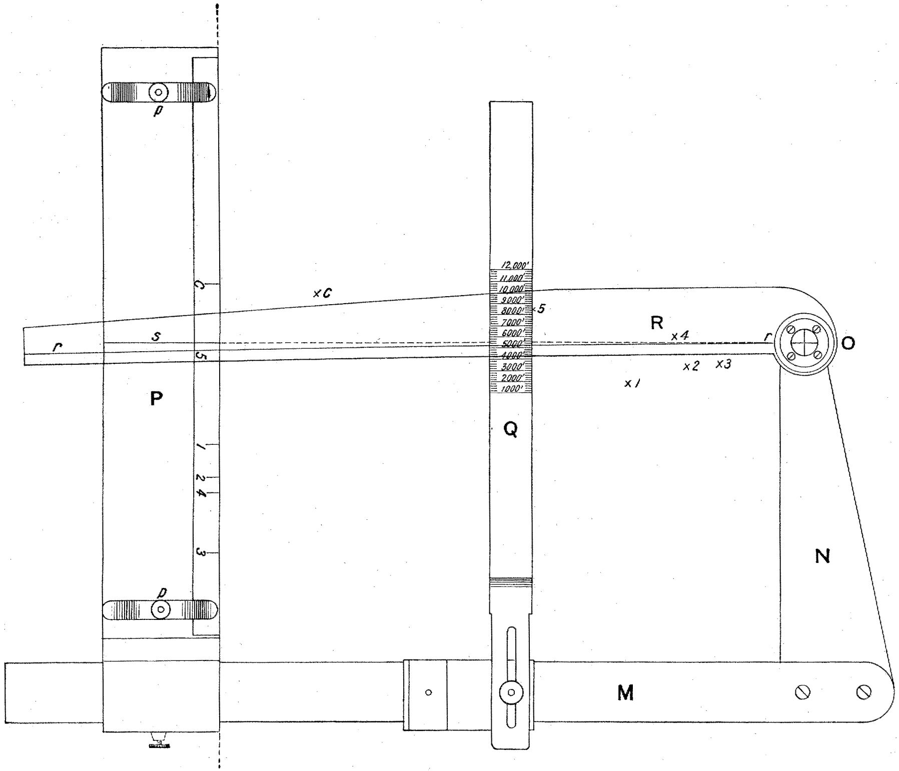


FIG. 4—Instrument devised by Messrs. D. B. Dowling and H. Matheson of the Canadian Geological Survey to determine the elevation of points plotted from photographic views. For explanation, see the text. In practice, the length of *s* from the center of *O* to the fiducial edge of *P* is made equal to the focal length of the views.

When using this instrument the center *O* is placed over the station, and the arm *P* is placed so that the edge coincides with the trace of the view, the line *s* falling on the principal line. The instrument is then held in place by heavy paper-weights. The distances of the points above or below the horizon as shown on the view are taken off on a slip of paper. The slip is then placed on *P*, as shown in the diagram, and held in position by the clips *p p*. The scale is now set to read the elevation of the station when the line *rr* is above *s*. To obtain the elevation of the point *5* the arm *Q* is moved to the point plotted and *R* is moved so that *rr* passes through *5* as shown on the slip. The elevation of the point is now read directly off the scale. To avoid mistakes the elevation of each point is taken from two views and the mean of the two elevations is used.

Relatively level topographic features such as swamps, lakes, and rivers with comparatively small fall are plotted by means of the perspectometer. This consists of the perspective of a series of squares drawn on glass, having the distance line equal to the focal length of the photograph. The projection of the squares is laid down on the plan, the perspectometer is placed in its proper position on the photograph and the outlines drawn in square by square. This method is illustrated in Figures 2 and 3.

The accuracy of a photographic map depends first of all on the precision of the triangulation. After that, it is dependent on the number of camera stations and on the scale of the plan. Any scale or contour interval may be used. These will be determined by the purpose for which the map is required. For general purposes, the writer considers a contour interval of one hundred feet and a scale of 1:40,000 the most convenient for a large plan. The precision is that of a good plane-table survey, but with the advantage that more points are plotted and the contouring is done by the surveyor in the office, with the views from the different stations before him to which he can refer alternately, while with a plane table this simultaneous comparison is entirely wanting.

The most tedious and tiresome part of the work is plotting the points and drawing the contours. The office work requires at least twice as long as the field work. This is not a defect but one of the greatest advantages of the method, for the field work, which is most expensive, requires much less time than when any other method is used.

A party of seven can work to the best advantage under most circumstances. The party consists of the surveyor, his assistant, and five men, two of whom should be expert packers if pack horses are used. With two sets of instruments, the surveyor and assistant surveyor, each accompanied by two men, are free to work in the same or different localities, the cook being left in charge of a main camp at some central point. Except on long or dangerous trips one man is enough to accompany the surveyor when actually climbing. If in a country unusually difficult of access, extra help may be advisable.

As regards the cost of the work, it is impossible to give any accurate estimate. The cost depends, in the first place, on the nature and accessibility of the country and, in the second place, on the class of work required. Much also depends on the season, as more or less time is always lost through smoky, cloudy, or rainy weather. The approximate cost of the writer's survey of the Crowsnest Forest Reserve in the years 1913-14 was $9.50 per square mile. This may be considered a fair average.

The following is a list of the principal photographic surveys made in Canada. The areas given are only approximate, particularly in the case of the earlier surveys.

LIST OF THE PRINCIPAL PHOTOGRAPHIC SURVEYS MADE IN CANADA

LOCALITY	AREA SURVEYED IN SQ. MILES	YEAR	SURVEYOR
Main range of the Rocky Mountains adjacent to Canadian Pacific Railway........	2,500	1886–92	J. J. McArthur
Columbia River valley from Revelstoke to Arrowhead	600	1897	J. J. McArthur
Alberta foothills south of Calgary........	2,000	1896–99	A. O. Wheeler
Crowsnest coal area, near Crowsnest Pass, B. C..................................	550	1900	A. O. Wheeler
Selkirk Mountains adjacent to Canadian Pacific Railway, from Beavermouth to Revelstoke..........................	1,100	1901–02	A. O. Wheeler
Rocky Mountains adjacent to Canadian Pacific Railway, from Mt. Castle to Beavermouth........................	2,200	1903–06	A. O. Wheeler M. P. Bridgland
Rocky Mountains, Robson district, north of Yellowhead Pass......................	1,100	1911	A. O. Wheeler
Rocky Mountains, Banff-Windermere road from Vermilion Pass to the junction of the Kootenay and Vermilion Rivers......	500	1913	R. D. McCaw
Crowsnest Forest Reserve, southwestern Alberta	1,500	1913–14	M. P. Bridgland
British Columbia—Alberta boundary.......	1,500	1913–15	A. O. Wheeler A. J. Campbell
Okanagan Lake district, British Columbia..	1,000	1914–15	R. D. McCaw
Jasper Park adjacent to Grand Trunk Pacific Railway........................	800	1915	M. P. Bridgland
British Columbia—Alaska boundary........	5,000	1893–1913	Dr. W. F. King
Southern boundary of British Columbia....	1,200	1903–05	J. J. McArthur
Yukon-Alaska Boundary (141st meridian)..	1,000	1907–13	J. D. Craig
Thirtyone-Mile Lake watershed, Quebec....	200	1913	D. H. Nelles
Reconnaisance surveys by the Geological Survey	9,000	1904–15	